SDSS *u'g'r'i'z'* Open Cluster Survey:

The Photometric Properties of NGC 6134 and Hogg 19

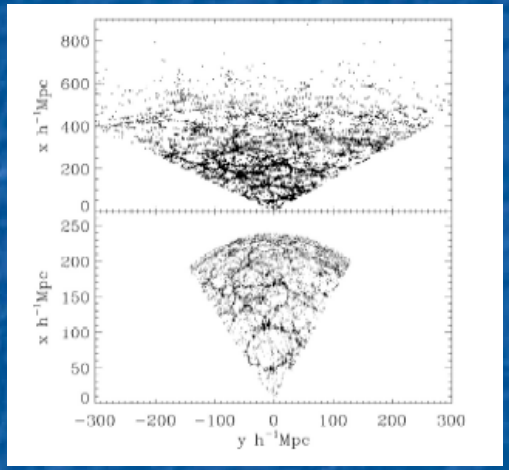
Credit: http://www.sdss.org

Credit: SMARTS consortium

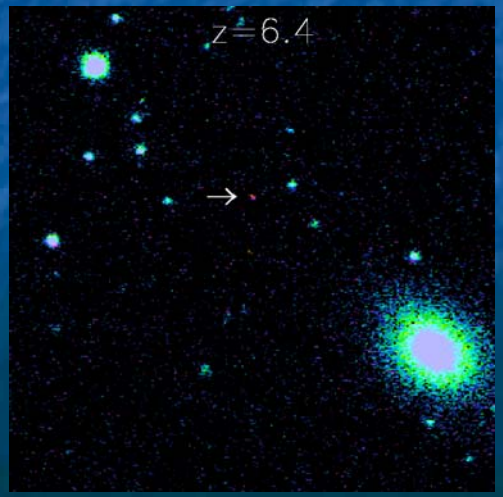
The Sloan Digital Sky Survey

- SDSS aims to obtain high-resolution imaging of _ of the entire sky in five different colors (*ugriz* filter set)

- Main goals of SDSS:
  - Mapping of large-scale structure (galaxies and quasars)
  - Accurate redshifts using spectroscopy (10^6 galaxies, 10^5 quasars)
  - SDSS looks back in time as it looks farther out in space



Wedge diagram of galaxy distributions (Doroshkevich et al. 2004)



z=6.4 quasar: 13 billion lyr

(universe ~800 million years old)

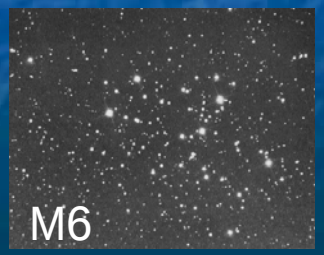
Credit: SDSS at Apache Point

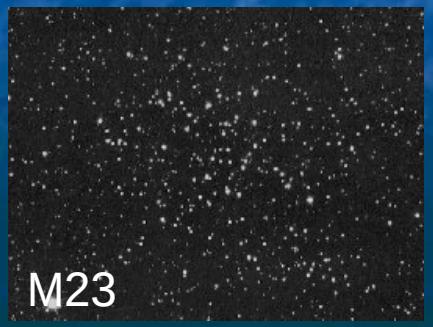
Spiral galaxy NGC 6070

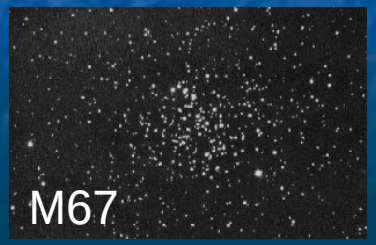
Credit: SDSS collaboration

Open Clusters

- Approximately 105 open clusters and 10 “low-density” globular clusters observed with *u’g’r’i’z’*
- Clusters span a range of ages and metallicities
  - Can be used to “back-calibrate” SDSS, and verify Girardi et al. (2004) isochrones
- Open clusters are interesting for stellar astrophysics because the stars in the cluster have roughly the same:
  - Distance
  - Age
  - Chemical composition
- But there are a variety of masses in the cluster, allowing for a sample of different stars for studies of stellar evolution



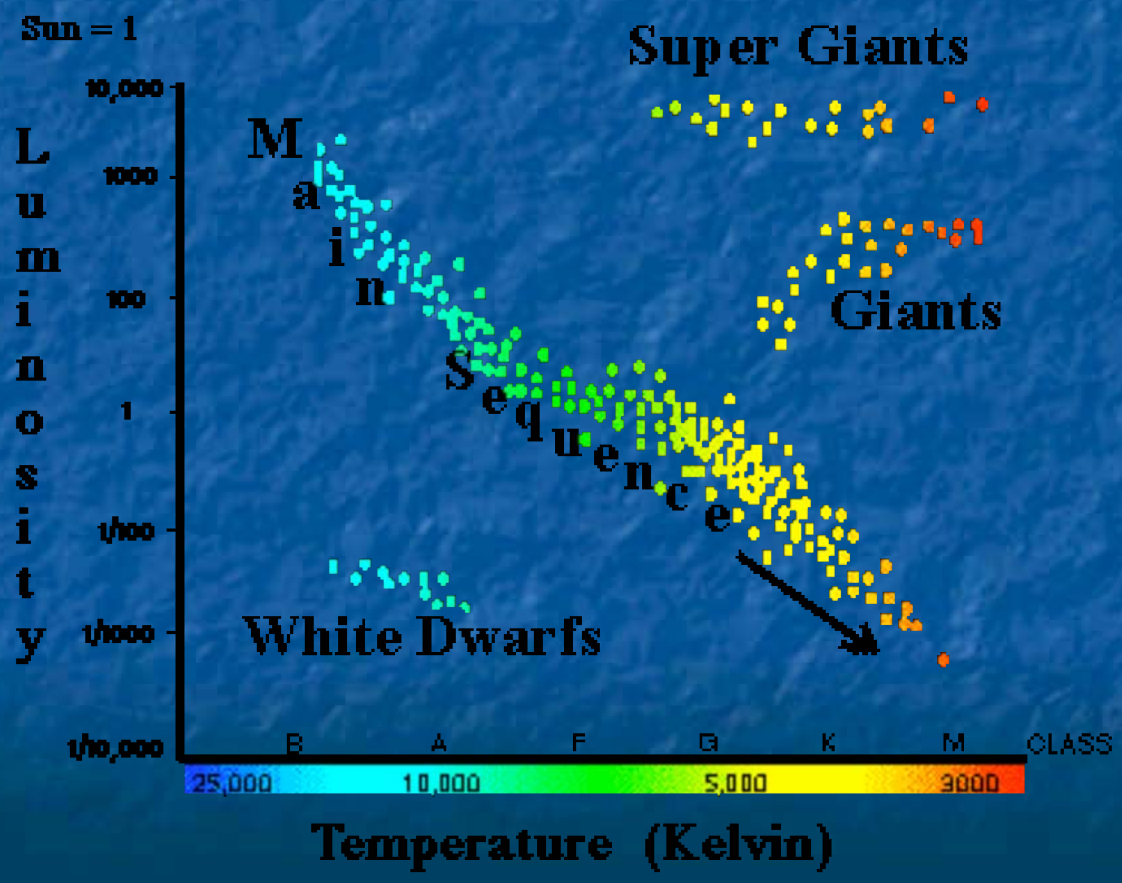




Credit: http://www.seds.org

H-R Diagrams

- There is a relationship between a star's "absolute" luminosity and it's temperature (or color)



Credit: http://www.smv.org/jims/l6.htm

- Most stars fall along the Main Sequence (the hydrogen burning phase of their life cycle)
- After burning their hydrogen, stars move off the main sequence to the Red Giant branch

H-R Diagrams and Stellar Evolution

Magnitudes and Colors

- Astronomers use a logarithmic scale to represent the luminosity of stars:

$$m_{AB} = -2.5 \log \frac{\int d(\log \nu)\, f_\nu S_\nu}{\int d(\log \nu) S_\nu} - 48.60$$

where f_ν is the flux per unit frequency incident on the atmosphere and S_ν is the system quantum efficiency

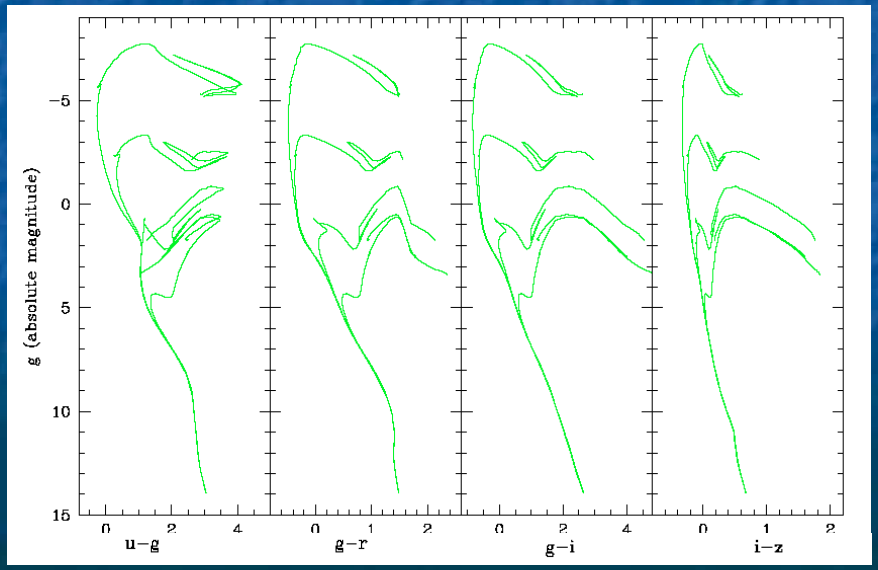
- The brighter the object, the smaller the magnitude!

- The color of an object can be represented by the difference in its magnitude between two filters
  - e.g. $(u' - g')$, $(g' - r')$, $(r' - i')$, and $(i' - z')$
- For black bodies, color is related to temperature by Wien's Law:

$$\lambda_{\max} \approx \frac{0.2897\ cm \cdot K}{T}$$

Theoretical Isochrones

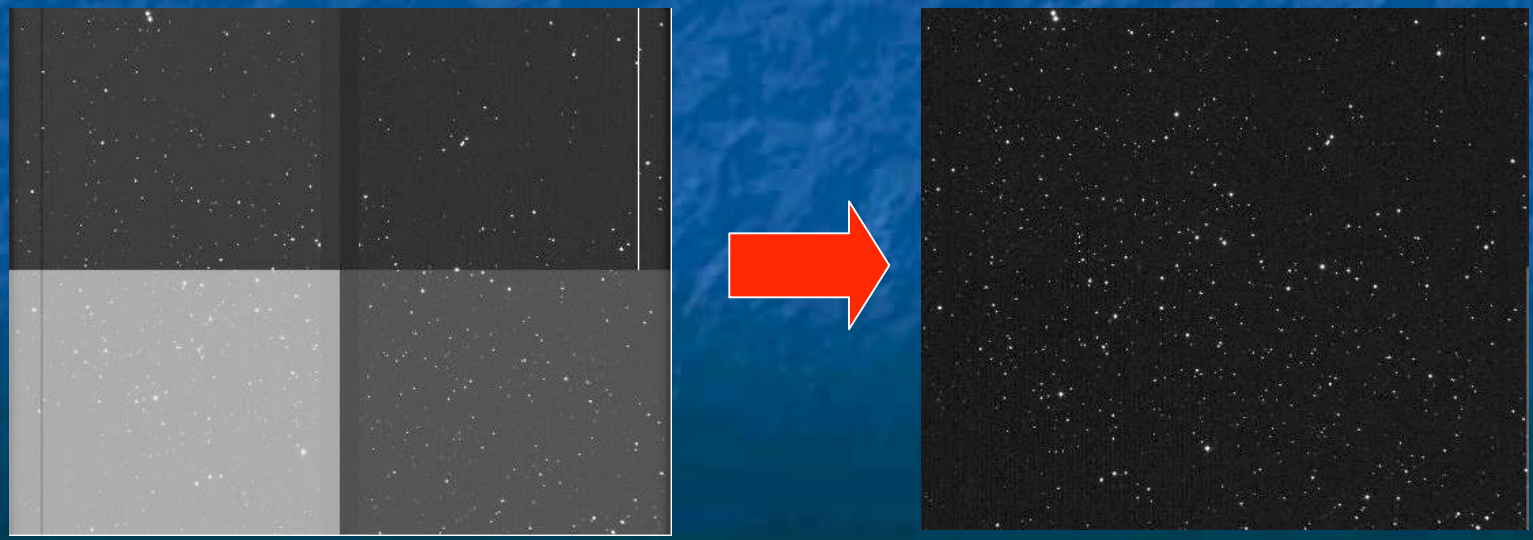
- Stars in open clusters are at approx. the same distance
  - The proportionality between “observed” and “absolute” luminosity for the stars is the same
- The stars in the cluster should lie along an “isochrone” dependent on age and metallicity
- For NGC 6134 and Hogg 19 we used the Girardi et al. (2004) isochrones for the *u’g’r’i’z’* system



Example of Girardi et al. (2004) color-magnitude diagrams for a cluster of solar metallicity with increasing age (10^7,10^8,10^9,10^{10} years)

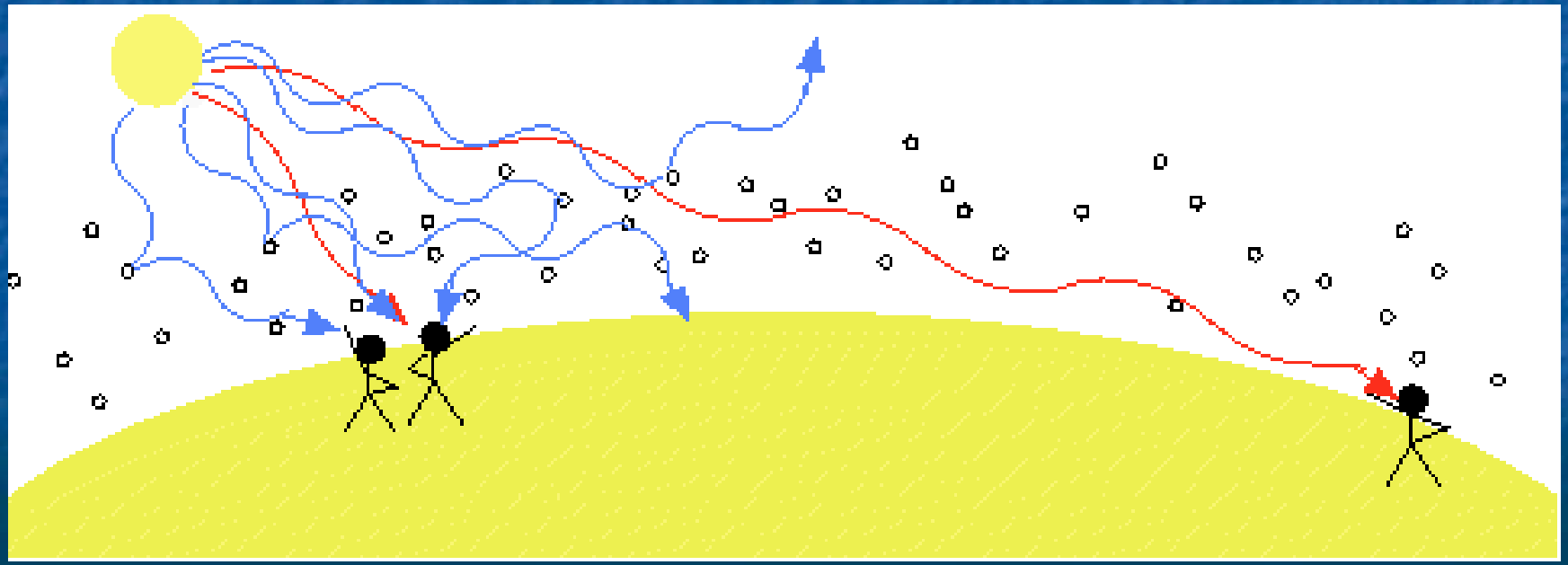
Data Reduction

- We have “raw” images from two telescopes from which we need to extract the actual photons hitting the detector (and infer the photons actually leaving the star)
  - The images of Hogg 19 and NGC 6134 were reduced with version 8.1 of the SDSS pipeline (`mtFrames`, `excal`, and `kali`)
  - `mtFrames` performs flat-fielding, bias subtraction, and aperture photometry
  - `excal` finds photometric zeropoints using standard star fields
  - `kali` applies the fitted photometric data to the lists of aperture photometry



Interstellar Reddening

- The stars were dereddened with the Girardi et al. (2004) extinction coefficients
  - Stars we observe have been “reddened” by clouds of dust
  - Shorter wavelengths are more likely to interact with the dust particles and not reach our detector



Credit: http://www.astronomynotes.com

Isochrone Fits

- After reducing the images with `mtpipe`, we had a list of aperture photometry from both the CTIO 0.9 m and CTIO Curtis-Schmidt telescopes
- The lists were combined – if an object was in both lists, the observed magnitude with the smallest photon noise was used
- We matched our data with existing data in the WEBDA open cluster database and plotted the isochrones over top our dereddened data
  - For NGC 6134, proper motion studies were available to assign a cluster membership probability
  - Coordinates of Red Giants, Spectroscopic Binaries, and cluster stars were also available
  - No data were available for Hogg 19

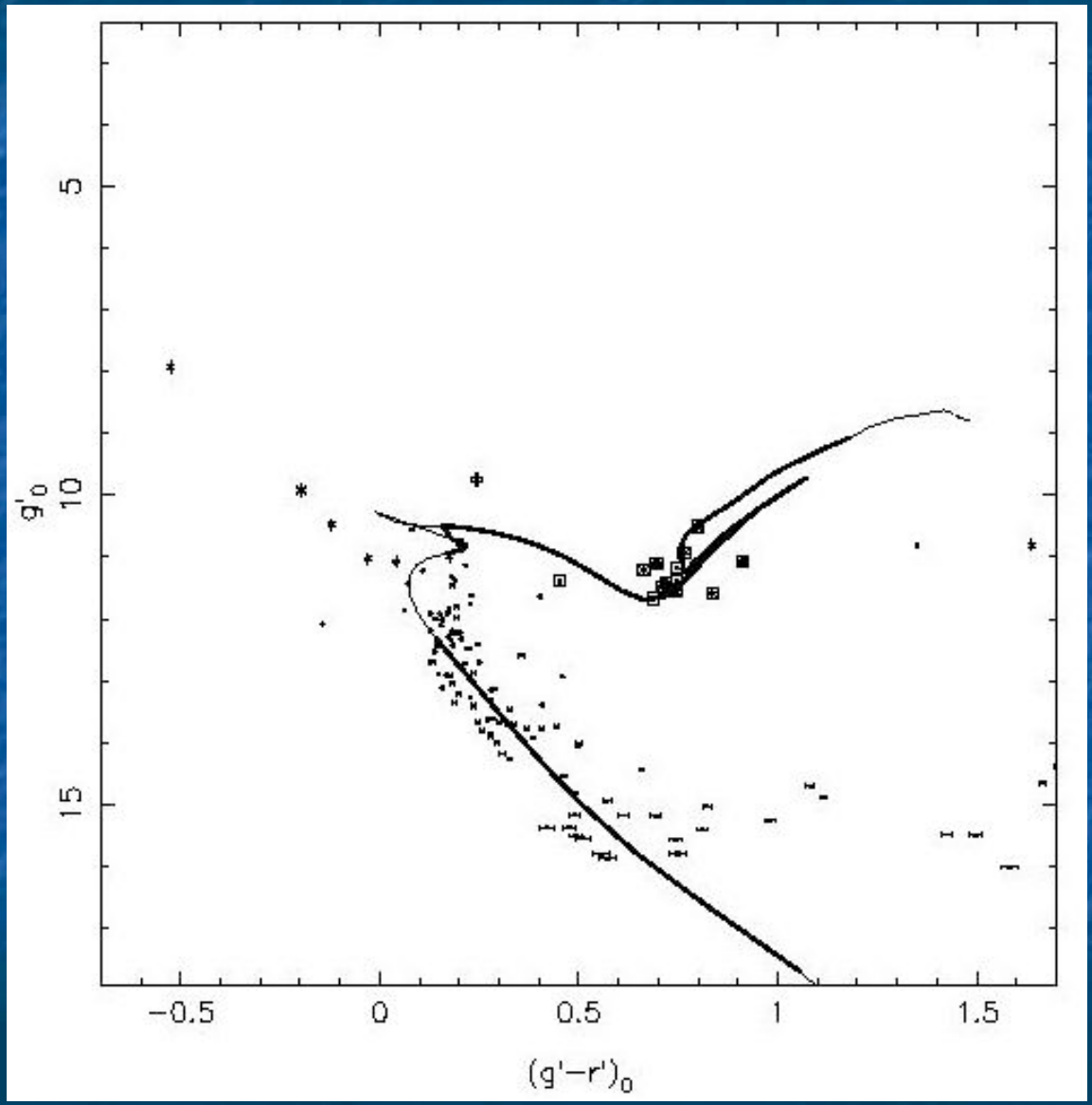
CTIO 0.9 m

CTIO Curtis-Schmidt

NGC 6134

- NGC 6134 is an intermediate age, moderately concentrated open cluster
- Several past studies have determined distance, age, and metallicity by fitting theoretical isochrones
- We used *u'g'r'i'z'* filters and Girardi et al. (2004) isochrones

NGC 6134: Results



We find:

Distance = 800±100 pc

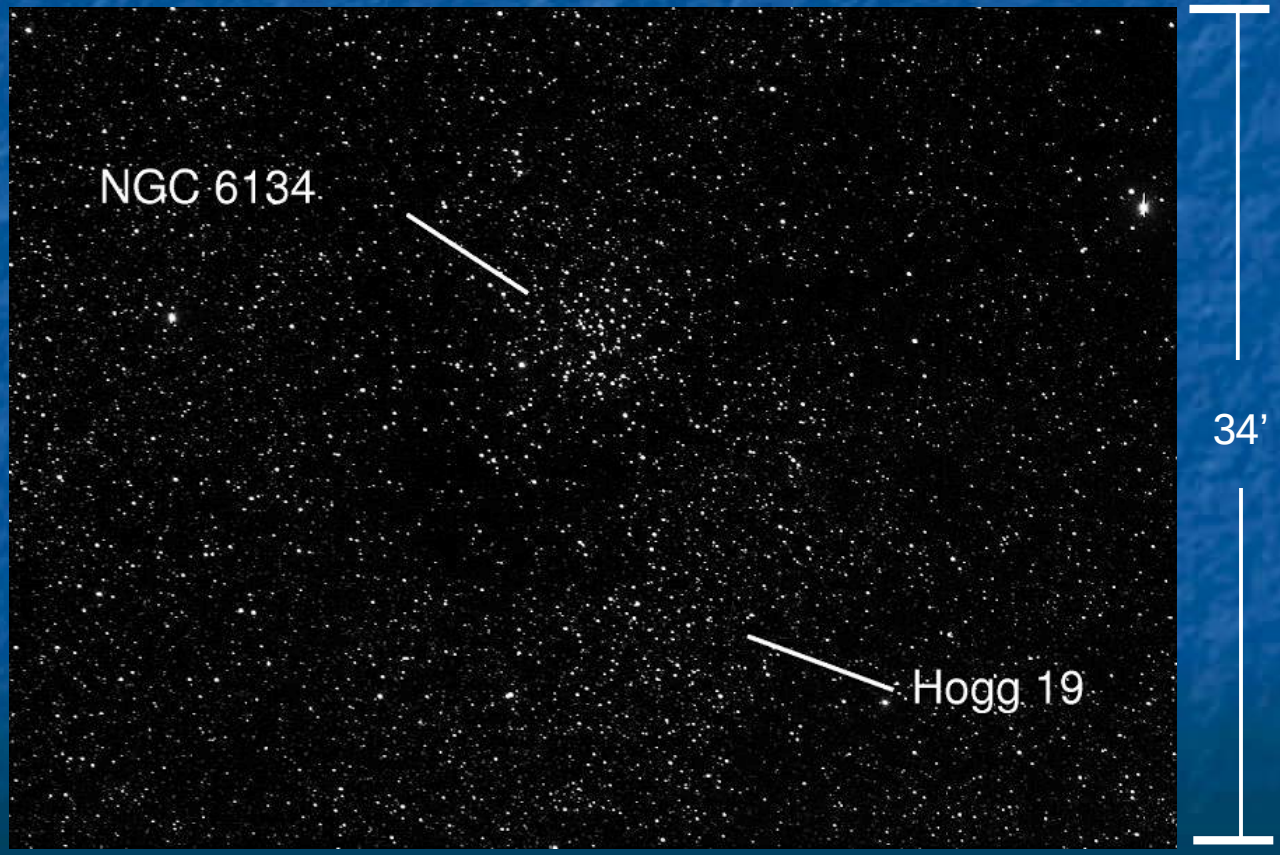
Age = 1.0 ±0.2 Gyr

$[Z/Z_\odot]$ = 0.0 ±0.1

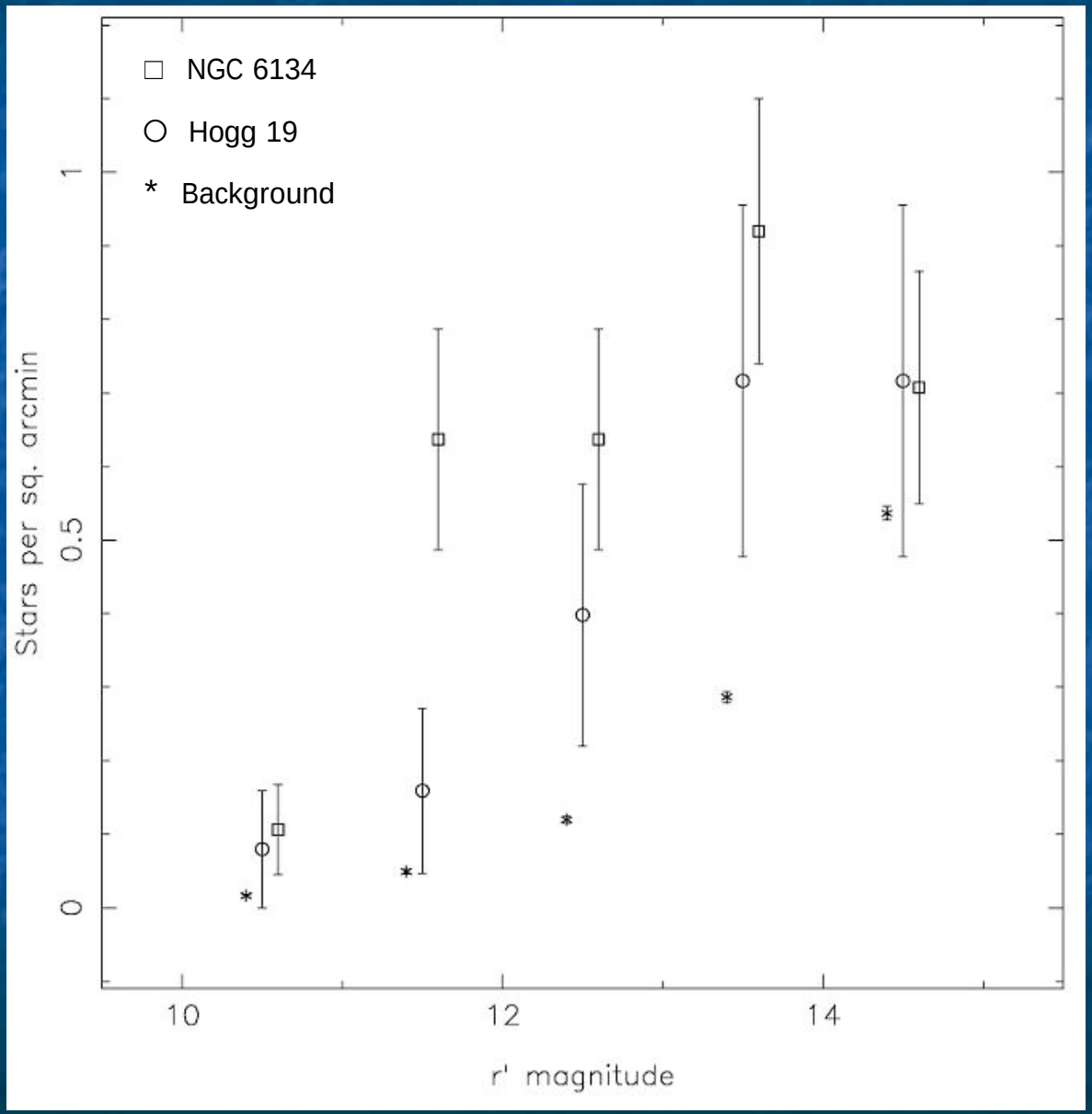
Our results are in agreement with previous studies, although we find a lower metallicity than the recent study by Bruntt et al. (1999)

Hogg 19

- Hogg 19 is a sparse open cluster which adjoins NGC 6134, first discovered by A. R. Hogg (1965)
  - If Hogg 19 exists, it is barely discernable from the background stars
  - Contamination from the field stars reduces the precision with which the isochrones can be fit to the cluster stars



Does Hogg 19 exist?



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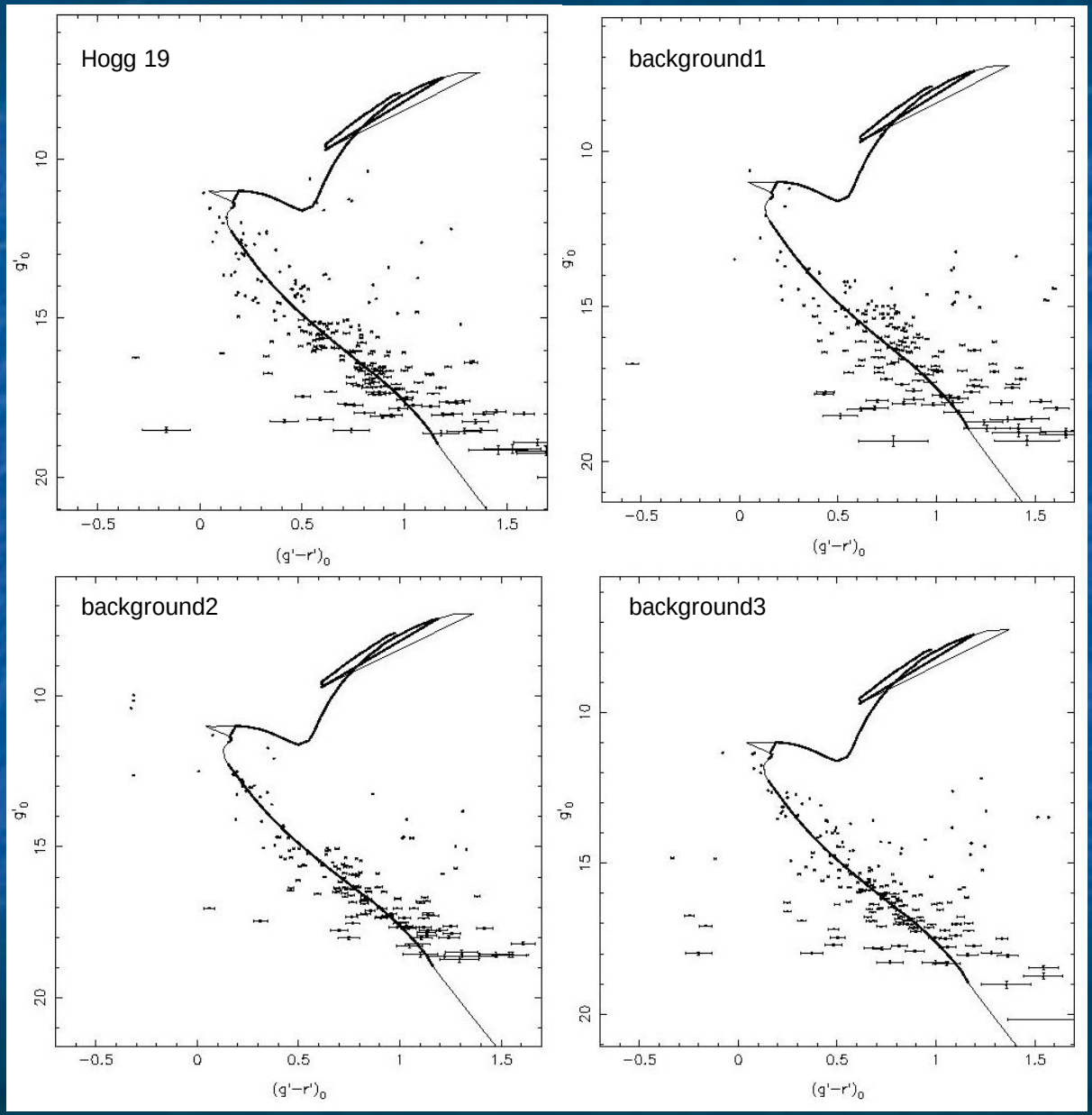
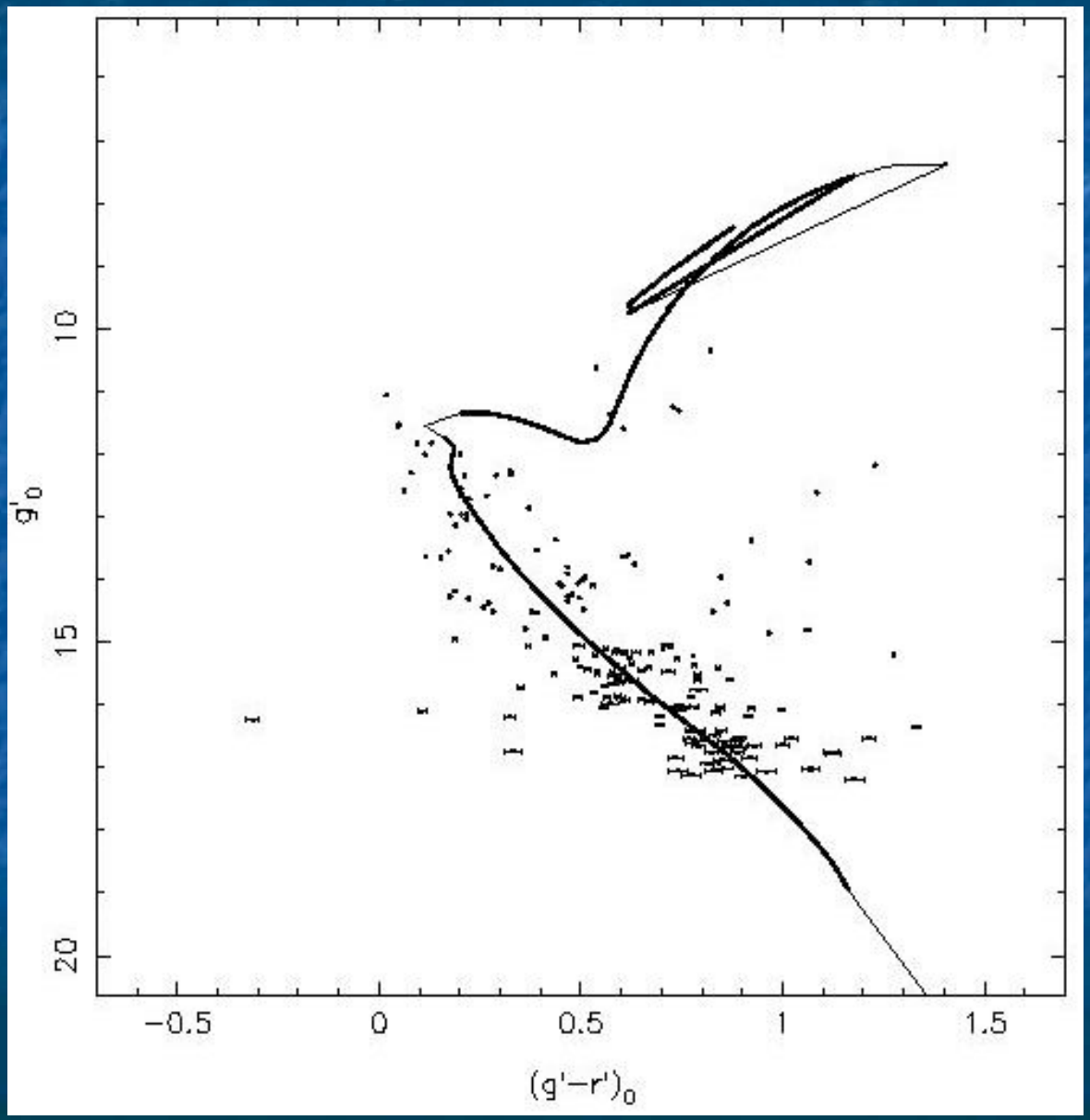


Hogg 19

- Unlike NGC 6134, no previous study which had fit isochrones
- There were no proper motion studies or accepted values on which to base our fits
- Due to the sparseness of the cluster and the lack of data, the precision with which we could fit isochrones was limited

Hogg 19: Results



We find the data are consistent with:

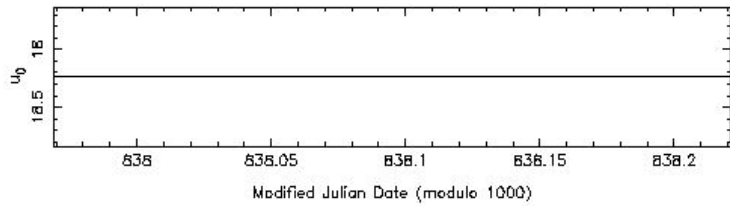
Distance = 550±100 pc

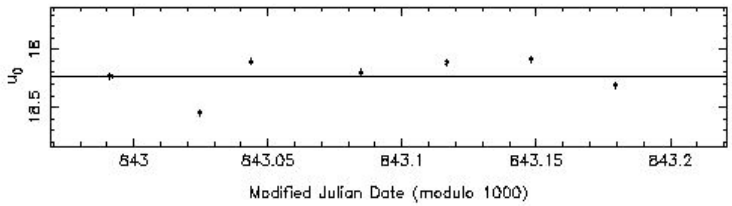
Age = 3.75 ±1.25 Gyr

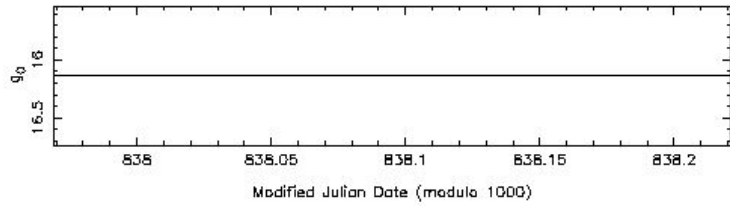
$[Z/Z_\odot]$ = -0.8 ±0.4

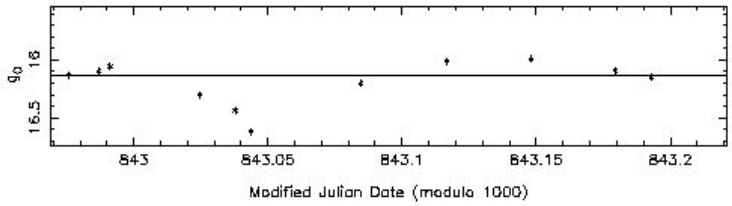
We were unable to make a robust determination of age or metallicity, although it appears to be quite old and metal poor

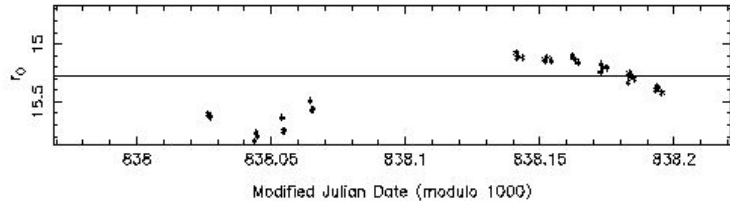
Variable Stars

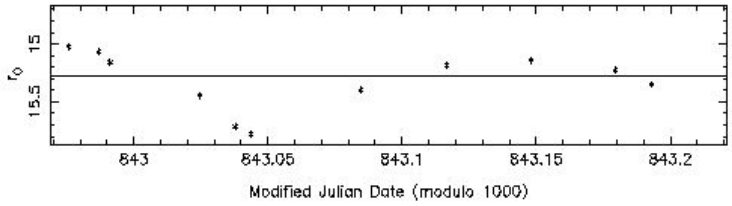


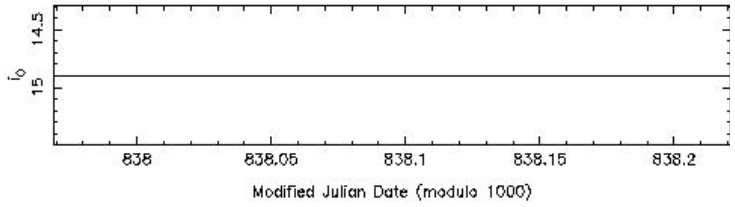


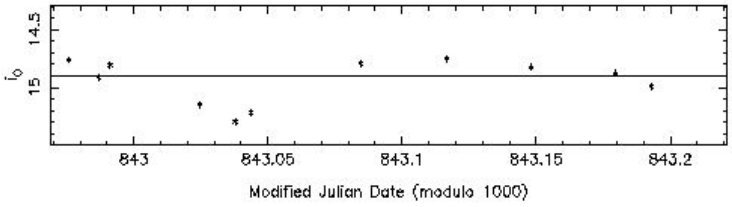


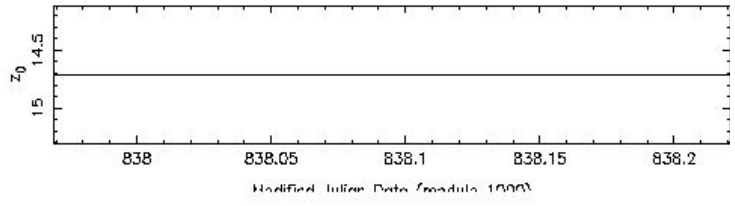


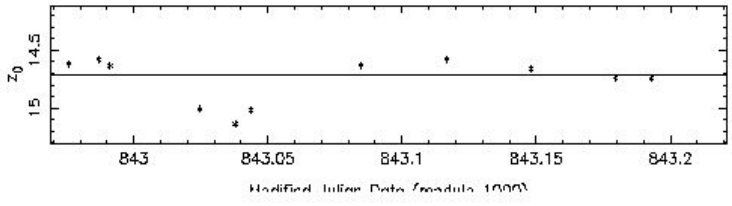












Summary and Future Work

- We analyzed the *u'g'r'i'z'* photometry of NGC 6134 and Hogg 19 and plotted C-M and C-C diagrams
- For NGC 6134, we were able to determine values for distance (~800 pc), age (~1.0 Gyr), and metallicity ($[Z/Z_{\odot}] \approx 0.0$)
- Our data indicate that Hogg 19 exists (due to presence of several red giants in the Hogg field)
- We find the data consistent with a distance of ~550 pc for Hogg 19, but cannot make a robust determination of age or metallicity
- Spectroscopy may be taken on Hogg 19 to better determine cluster membership (or existence)
- Future studies will be conducted on the remaining clusters in the survey – the immediate goal is to publish a sample of open clusters covering a range of ages and metallicities
- Repeat observations may be pursued to hunt for variables stars (to improve distance estimates)

Acknowledgements

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  - Douglas Tucker
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  - The interns